

What is claimed is:

1. A quartz crystal resonator being a flexural mode, quartz crystal tuning fork resonator, said tuning fork resonator comprising:

tuning fork tines; and

5 a tuning fork base, to which said tuning fork tines are attached,

wherein a groove is provided on at least one of an obverse face and a reverse face of said tuning fork tines, and a first electrode is disposed inside said groove and a second electrode is disposed on both sides of said tuning fork tines,

10 and wherein a piezoelectric constant  $e_{12}$  of said resonator is within a range of  $0.095 \text{ C/m}^2$  to  $0.19 \text{ C/m}^2$  in the absolute value.

2. The quartz crystal resonator according to claim 1, wherein figure of merit  $M_1$  for a fundamental mode vibration of said resonator is larger  
15 than figure of merit  $M_2$  for a second overtone mode vibration thereof, and the  $M_1$  is larger than 65 and the  $M_2$  is less than 30.

3. The quartz crystal resonator according to claim 1, wherein a  
20 groove provided on either the obverse face or the reverse face of said tuning fork tines is a through hole.

4. A quartz crystal unit comprising: a flexural mode, quartz crystal tuning fork resonator; a case; and a lid, said quartz crystal tuning fork resonator comprising tuning fork tines and a tuning fork base, to which said  
25 tuning fork tines are attached,

wherein a groove is provided on both of an obverse face and a reverse face of said tuning fork tines, and a first electrode is disposed inside said groove and a second electrode is disposed on both sides of said tuning fork tines,

30 and wherein a piezoelectric constant  $e_{12}$  of said resonator is within a range of  $0.095 \text{ C/m}^2$  to  $0.19 \text{ C/m}^2$  in the absolute value.

5. The quartz crystal unit according to claim 4, wherein figure of

merit  $M_1$  for a fundamental mode vibration of said resonator is larger than figure of merit  $M_2$  for a second overtone mode vibration thereof.

6. The quartz crystal unit according to claim 5, wherein figure of  
5 merit  $M_1$  for the fundamental mode vibration is larger than 65, and figure of merit  $M_2$  for the second overtone mode vibration is less than 30.

7. The quartz crystal unit according to claim 5, wherein a ratio  
( $W_2/W$ ) of a groove width  $W_2$  and a tine width  $W$  of said tuning fork tines  
10 is greater than 0.35 and less than 1, and a ratio ( $t_1/t$ ) of a groove thickness  $t_1$  and a tine thickness  $t$  of said tuning fork tines is less than 0.79.

8. The quartz crystal unit according to claim 5, wherein a groove  
area  $S$  of said tuning fork tines is within a range of  $0.025 \text{ mm}^2$  to  $0.12 \text{ mm}^2$ .  
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9. The quartz crystal unit according to claim 5, wherein a ratio  
( $l_1/l$ ) of a groove length  $l_1$  and a total length  $l$  of said resonator is within a  
range of 0.2 to 0.78.

10. The quartz crystal unit according to claim 5, wherein when  
20 stable factors of frequency,  $S_1$  and  $S_2$  of the fundamental mode vibration and the second overtone mode vibration of said quartz crystal tuning fork resonator are given by  $S_1=r_1/2Q_1^2$  and  $S_2=r_2/2Q_2^2$ , respectively,  $S_1$  is less than  $S_2$ .

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11. A quartz crystal oscillator comprising: a quartz crystal  
oscillating circuit comprising; an amplification circuit comprising a CMOS  
inverter and a feedback resistor, and a feedback circuit comprising a  
flexural mode, quartz crystal tuning fork resonator, capacitors and a drain  
30 resistor, said quartz crystal tuning fork resonator comprising tuning fork  
tines and a tuning fork base, to which said tuning fork tines are attached,  
wherein a groove is provided on both of an obverse face and a reverse  
face of said tuning fork tines,

and wherein a piezoelectric constant  $e_{12}$  of said resonator is within a range of  $0.095 \text{ C/m}^2$  to  $0.19 \text{ C/m}^2$  in the absolute value.

12. The quartz crystal oscillator according to claim 11, wherein said  
5 quartz crystal oscillating circuit comprises said quartz crystal tuning fork resonator having figure of merit  $M_1$  for a fundamental mode vibration larger than figure of merit  $M_2$  for a second overtone mode vibration to suppress the second overtone mode vibration and to get a high frequency stability for the fundamental mode vibration.

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13. The quartz crystal oscillator according to claim 12, wherein a ratio( $\alpha_1/\alpha_2$ ) of said oscillating circuit is greater than a ratio( $\beta_2/\beta_1$ ) thereof, and a product of  $\alpha_1$  and  $\beta_1$  is greater than 1.

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14. The quartz crystal oscillator according to claim 12, wherein a ratio( $|-RL_1|/R_1$ ) of said oscillating circuit is greater than a ratio( $|-RL_2|/R_2$ ) thereof.

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15. The quartz crystal oscillator according to claim 12, wherein a value of ( $|-RL_1|/R_1$ ) of said oscillating circuit is greater than a value of ( $2|-RL_2|/R_2 - 1$ ) in said oscillating circuit.

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16. The quartz crystal oscillator according to claim 12, wherein an output signal of said quartz crystal oscillating circuit is outputted through a buffer circuit, and an oscillation frequency deviation of the output signal is within a range of  $-100 \text{ PPM}$  to  $+100 \text{ PPM}$  to a nominal frequency of  $32.768 \text{ kHz}$ .

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17. An electronic apparatus comprising a display portion and a quartz crystal oscillator at least, said electronic apparatus having at least one quartz crystal oscillator, one of the at least one quartz crystal oscillator comprising:

a quartz crystal oscillating circuit comprising; an amplification circuit

comprising an amplifier and a feedback resistor, and a feedback circuit comprising a quartz crystal resonator, capacitors and a drain resistor,

said quartz crystal resonator being a flexural mode, quartz crystal tuning fork resonator, said quartz crystal tuning fork resonator comprising  
5 tuning fork tines and a tuning fork base, to which said tuning fork tines are attached,

wherein a groove is provided on at least one of an obverse face and a reverse face of said tuning fork tines, and a first electrode is disposed inside said groove and a second electrode is disposed on both sides of said  
10 tuning fork tines,

and wherein a piezoelectric constant  $e_{12}$  of said resonator is within a range of  $0.095 \text{ C/m}^2$  to  $0.19 \text{ C/m}^2$  in the absolute value.

18. The electronic apparatus according to claim 17, wherein a ratio  
15  $(|-RL_1|/R_1)$  of said oscillating circuit is greater than a ratio  $(|-RL_2|/R_2)$  thereof, and said quartz crystal oscillating circuit comprises said quartz crystal tuning fork resonator having figure of merit  $M_1$  of a fundamental mode vibration larger than figure of merit  $M_2$  of a second overtone mode vibration to suppress the second overtone mode vibration and to get a high  
20 frequency stability for the fundamental mode vibration.

19. The electronic apparatus according to claim 18, wherein an output signal of said quartz crystal oscillating circuit has an oscillation frequency of the fundamental mode vibration of said flexural mode, quartz  
25 crystal tuning fork resonator, and said output signal is a clock signal which is used to display time at said display portion of said electronic apparatus.

20. The electronic apparatus according to claim 19, wherein a quartz crystal unit has one of a length-extensional mode quartz crystal resonator, a  
30 thickness shear mode quartz crystal resonator, a width-extensional mode quartz crystal resonator, a Lamé mode quartz crystal resonator and a SAW resonator, and at least one quartz crystal oscillator comprises a quartz crystal oscillating circuit comprising said quartz crystal unit.

21. The electronic apparatus according to claim 19, wherein at least one quartz crystal oscillator comprises: a quartz crystal oscillating circuit comprising; an amplification circuit comprising an amplifier and a  
5 feedback resistor, and a feedback circuit comprising a quartz crystal resonator, capacitors and a drain resistor, said quartz crystal resonator being a length-extensional mode quartz crystal resonator, and said length-extensional mode resonator comprising: a vibrational portion having a length greater than a width and a thickness smaller than the width;  
10 connecting portions located at ends of said vibrational portion; supporting portions connected to said vibrational portion through said connecting portions; electrodes disposed opposite each other on upper and lower faces of said vibrational portion, a piezoelectric constant  $e_{12}$  of said length-extensional mode resonator being within a range of  $0.095 \text{ C/m}^2$  to  $0.19$   
15  $\text{C/m}^2$  in the absolute value, an output signal of said quartz crystal oscillating circuit comprising said length-extensional mode resonator being outputted through a buffer circuit, and said output signal being a clock signal which is used except time display of said electronic apparatus.

20 22. A method for manufacturing an electronic apparatus comprising a display portion and a quartz crystal oscillator at least, said electronic apparatus comprising at least one quartz crystal oscillator, said at least one quartz crystal oscillator comprising:

a quartz crystal oscillating circuit comprising; an amplification circuit  
25 comprising a CMOS inverter and a feedback resistor, and a feedback circuit comprising a quartz crystal resonator, capacitors and a drain resistor,

said quartz crystal resonator being a flexural mode, quartz crystal tuning fork resonator, said quartz crystal tuning fork resonator comprising the steps of:

30 forming integrally a first tuning fork tine and a second tuning fork tine, and a tuning fork base;

disposing an electrode on both sides of the first tuning fork tine and the second tuning fork tine so that the electrodes disposed on inner sides of

the first and second tines are of opposite electrical polarity; and

adjusting an oscillation frequency of said quartz crystal tuning fork resonator after mounting it at a mounting portion by conductive adhesives or solder so that a frequency deviation of an output signal of said quartz crystal oscillating circuit is within a range of  $-100$  PPM to  $+100$  PPM to a nominal frequency of  $32.768$  kHz, and

said at least one quartz crystal oscillator comprising the step of:

constructing said quartz crystal oscillating circuit so that a ratio of an absolute value of negative resistance,  $|-RL_1|$  of a fundamental mode vibration of said amplification circuit and series resistance  $R_1$  of the fundamental mode vibration is larger than that of an absolute value of negative resistance,  $|-RL_2|$  of a second overtone mode vibration of said amplification circuit and series resistance  $R_2$  of the second overtone mode vibration,

said quartz crystal oscillating circuit comprising said quartz crystal tuning fork resonator having figure of merit  $M_1$  of the fundamental mode vibration larger than figure of merit  $M_2$  of the second overtone mode vibration to suppress the second overtone mode vibration and to get a high frequency stability for the fundamental mode vibration, and

a piezoelectric constant  $e_{12}$  of said quartz crystal tuning fork resonator being within a range of  $0.095$  C/m<sup>2</sup> to  $0.19$  C/m<sup>2</sup> in the absolute value.

23. The method of claim 22, comprising the further steps of forming tuning fork resonators in a quartz crystal wafer and inspecting them in the quartz crystal wafer, and when there is a failure resonator therein, it is removed from the wafer, or something is marked on it, or it is remembered by a computer.